

بسم الله الرحمن الرحيم
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Proportions of an axial Wind Turbine to be used in North of Sudan

***Thesis submitted in partial
fulfillment to the college of
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:By

(Badri Mohamed ALfaki (P.G.D

-:Supervised By

Prof. William Ibrahim Asaad

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Abstract

This study has been carried out to exploit the wind energy to lift water from deep well for domestic use in the north of Sudan where the wind is available.

The result of this study gave the estimation of proportions of five blades with tubes on the concave sides with supporting horizontal axis against the wind to achieve the task.

الخلاصه

**تم اعداد هذه الدراسه لاستغلال طاقه الرياح لرفع مياه
جوفية للاستخدامات المنزليه فى شمال السودان حيث الرياح
متوفره**

هذه الدراسة خلصت الى حساب ابعاد تربينه هوائيه تتكون
من خمس ريش م مقوسة بمحور افقى لاستغلال الطاقة فى رفع
كميه الماء المطلوبة.

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SYMBOLS

		Units
A	Rotor swept area	m^2
A_1	Area on the upstream side of the rotor	m^2
A_2	Area on the downstream side of the rotor	m^2
a	Axial induction factor	
b	Tangential induction factor	
B	Number of blades	
D	Drag force	N
D_p	Pump piston diameter	m
d_d	Diameter of the delivery pipe	m
d_p	Diameter of the pump rod	m
C	Chord width	m
C_D	Drag coefficient	

C_L	Lift coefficient	
C_P	Power coefficient	
C_T	Torque coefficient	
L	Pump stroke	m
L_d	Length of the delivery pipe	m
L_s	Span length	m
F_a	Axial force	N
F_d	Driving force	N
f	Friction factor	
P_a	Atmospheric pressure	N/m^2
P_x	Upstream pressure	N/m^2
P_y	downstream pressure	N/m^2
P_b	blade power	watt
V	Wind speed	m/sec
V_1	Upstream wind speed	m/sec
V_2	Downstream wind speed	m/sec
V_r	Relative speed	m/sec
U	Speed of the rotor	m/sec
T_b	Torque on the blade	Nm

GREEK SYMBOLS

α	Angle of attack	degree
b	Blade setting angle	degree
f	Angle between the relative velocity and the Rotor speed	degree
λ	Tip speed ratio	
λ_r	Local tip speed ratio	
ρ	Air density	kg/m^3
ρ_s	Steel mass density	kg/m^3
ω	Angular speed of the rotor	rad/sec
Ω	Yaw angular speed	rad/sec

REFERENCES

- 1) Eisa. Eltyab Idris. "A design study for wind pump system for use in Sudan" , University of Reading , 1980
- 2) CABLE, Ex.lysen., "Introduction to wind energy", Endhaven ,1983
- 3) Yahya,S M , "Turbine ,Compressor and Fan", New Delhi,1983
- 4) CWD,"Design report 1500 windmill". Netherlands. (1983)
- 5) Sharif, Mohamed .," The year of water", Swiss info ,Geneva ,Switzerland January 2003
- 6) Teferi, T."Wind energy harnessing – theory and the Ethiopian experience ", Journal of the ESME,Voll,No2 October 1999
- 7) Jain.A.K."fluid mechanics ", Delhi, Sep. 1999